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Heavy metal contamination in swiftlet feathers: A comparative study of chromium and arsenic levels in industrial and non-industrial areas of East Java, Indonesia

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Abstract

This study examines the levels of chromium (Cr) and arsenic (As) in the feathers of edible-nest swiftlets (*Aerodramus fuciphagus*) from two distinct environments: an industrial area in Gresik, and a non-industrial area in Nganjuk, Indone-sia. Feather samples were collected from swiftlet houses in both locations and analyzed using an X-Ray Fluorescence (XRF) Analyzer. The results revealed that the average Cr concentration in feathers from Gresik was 3.36 ppm, compared to 1.49 ppm in Nganjuk. Similarly, the average As concentration in Gresik was 2.34 ppm, whereas in Nganjuk obtained it was 1.22 ppm. These differences may be attributed to factors such as air quality in flight areas, the drinking water consumed by the birds, and the quality of their food sources. The findings indicate that swiftlets inhabiting industrial regions are exposed to higher levels of heavy metals, highlighting the influence of environmental conditions on bioaccumulation. This study underscores the potential of swiftlet feathers as bioindicators of environmental pollution.

Keywords

Biomonitoring, Swiftlet, Chromium, Arsenic, X-Ray fluorescence

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Introduction

Environmental pollution, especially from heavy metals, poses significant threats to ecological stability [1], including air quality degradation. Air pollution particularly impacts vulnerable populations such as infants, children, women, the elderly, and individuals with chronic health conditions like cardiorespiratory diseases, as well as those with limited social support and insufficient access to healthcare [2]. Shifts in an ecosystem's biodiversity often reveal underlying causes of ecological health decline [3].

Birds, as bioindicators, play a vital role in monitoring heavy metal pollution due to their ability to accumulate airborne contaminants [4][5].

Bird feathers serve as an effective bioindicator for environmental monitoring [6]. Originating from the skin, feathers have the capacity to accumulate metals [7]. Their collection is straightforward and non-invasive, ensuring no harm to the birds [8]. Feathers can retain trace elements absorbed from contaminated food sources and polluted environments [9]. Metals in feathers bind to keratin, a sulfur-rich protein with a strong affinity for specific metals. Research by Tingting Yao [1] demonstrates a significant positive correlation ($p < 0.05$) between the metal content in feathers and that in the bird's body tissues.

The edible-nest swiftlet (*Aerodramus fuciphagus*) is widely found in South China and Southeast Asia, including Indonesia, which is recognized as one of the world's largest producers of swiftlet nests. The practice of cultivating these nests in Indonesia dates back to the 18th century [10]. Originally nesting in natural caves, swiftlets have also adapted to artificial structures [11]. Research indicates that their average core territory spans approximately 1,687.06 hectares (16.87 km²), while their overall range extends to about 6,437.47 hectares (64.37 km²), with typical foraging distances between 2 to 6 kilometers from their nesting sites [12]. Remarkably, swiftlets spend the majority of their lives in flight, covering up to 200,000 kilometers annually [13]. These unique behaviors make them valuable bioindicators for monitoring environmental quality, particularly in detecting heavy metal pollution.

In this study, two heavy metals were measured: arsenic and chromium. Arsenic (As) is a regulated hazardous material in the environment and a persistent pollutant that causes environmental, agricultural, and health issues, posing a significant risk to humans [14]. This heavy metal is a naturally occurring toxic metalloid that is widespread in the environment. It is present in water, soil, and air, and consequently is also found in the food supply [15]. This study aims to compare chromium (Cr) and arsenic (As) levels in swiftlet feathers from industrial and non-industrial areas, utilizing X-Ray Fluorescence (XRF) analysis to assess environmental pollution.

Method

This research is a quantitative descriptive study involving sampling feathers from five individual swiftlets at two locations: Gresik (industrial) and Nganjuk (non-industrial). Each sample consisted of 20-50 mg of feathers. Purposive sampling ensured the representativeness of the differing environmental conditions. Feather samples were analyzed using an XRF Analyzer. This technique provides precise, non-invasive identification of chemical elements by detecting fluorescent X-rays emitted from excited atoms. The limited sample size is acknowledged as a constraint; future studies should include larger datasets for improved analysis. The environmental conditions around the swiftlet nests in Gresik (6°59'28.9"S 112°33'46.6"E) consist of residential areas and factories that operate every day. These factories and residential areas

produce emissions that can pollute the air around the swiftlet nests. The second location is in Nganjuk (7°33'18.9"S 111°44'05.7" E), the location is more natural and far from human activities. The differences in these two environmental conditions are shown in Figure 1.

(a) (b)

Figure 1. Satellite imagery of the sampling location for swiftlets feather in Gresik (a) and Nganjuk (b)

Results and Discussion

Results

The XRF analysis in this study revealed that the levels of Arsenic (As) and Chromium (Cr) in bird feathers from Gresik are higher compared to those from Nganjuk. These findings align with previous research, which indicated that differences in pollutant exposure levels across regions are likely related to the intensity of industrial activities and urbanization in each area [16]. Detailed information on the concentrations of As and Cr is presented in Table 1.

Table 1. XRF test results

Location	Sample Number	Heavy metal content (ppm)	
		As	Cr
Gresik	G1	2.12	3.96
	G2	2.42	4.12
	G3	2.92	3.75
	G4	1.92	4.22
	G5	2.31	3.23
Nganjuk	N1	0.92	1.27
	N2	1.12	2.12
	N3	1.45	1.32
	N4	1.36	1.22
	N5	1.23	1.53

The results of the XRF analysis, as summarized in Table 1, indicate a significantly higher concentration of Arsenic (As) and Chromium (Cr) in bird feathers from Gresik compared to those from Nganjuk. Specifically, the average As concentration in Gresik samples ranges from 1.92 to 2.92 ppm, while Cr ranges from 3.23 to 4.22 ppm. In contrast, the Nganjuk samples exhibit lower As concentrations (0.92–1.45 ppm) and Cr concentrations (1.22–2.12 ppm).

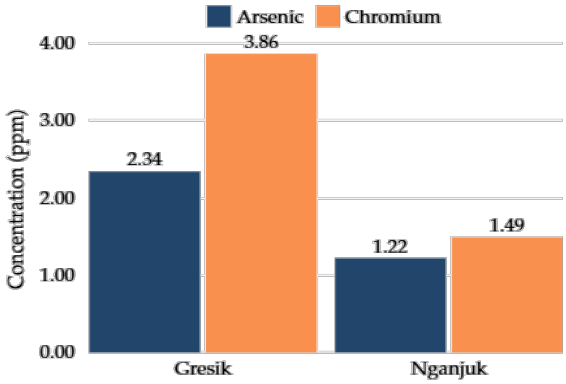

Figure 2. The average values of Arsenic and Chromium in Gresik and Nganjuk

Figure 2 shows that the average values of Arsenic and Chromium in Gresik are higher than in Nganjuk, and the average values of Arsenic in both locations are higher than that of Chromium. Arsenic contamination is higher than chromium in Gresik due to industrial activities (coal waste, heavy metals) and the characteristics of limestone, while in Nganjuk it is due to intensive agricultural activities, the use of fertilizers and pesticides, and the weathering of volcanic rocks.

Discussion

The findings of this study provide valuable insights into the bioaccumulation of Arsenic (As) and Chromium (Cr) in swiftlet feathers and their relationship with varying environmental conditions in Gresik and Nganjuk. The notably elevated levels of arsenic and chromium in Gresik can primarily be attributed to the area's proximity to industrial and urban activities. Swiftlet houses in Gresik are strategically located closer to factories and densely populated residential zones. Industrial processes, particularly those involving metal refining, manufacturing, or chemical production, are known to release significant amounts of heavy metals such as arsenic and chromium into the atmosphere. These pollutants can deposit on various surfaces, including vegetation and soil, through air and water pathways. Over time, this contamination spreads into the local ecosystem [17].

Urbanization further exacerbates this issue by introducing multiple sources of heavy metal pollution. Vehicular emissions, for instance, are a consistent contributor to atmospheric chromium levels due to the use of chromium-based additives in fuel and lubricants. Similarly, construction activities disturb underlying soil layers, releasing arsenic and other trace elements into the immediate environment. Waste incineration, another common urban activity, often involves materials containing heavy metals, leading to their dispersal as fine particulate matter [18].

On the other hand, Nganjuk's relatively lower heavy metal concentrations reflect its more natural environmental context. The swiftlet houses in this area are located away from significant industrial zones, and while there may be some residential presence, the extent of urbanization is notably less than in Gresik. Natural environments, which are less impacted by human activities, tend to have reduced levels of anthropogenic

pollutants like arsenic and chromium. Consequently, wildlife and birds in these areas are exposed to fewer contaminants, resulting in lower heavy metal accumulation in their feathers.

This stark contrast in environmental settings underscores the profound impact of industrialization and urbanization on the deposition of heavy metals. It highlights the need for stricter environmental controls in industrial zones and ongoing monitoring of pollution levels to mitigate the risks associated with heavy metal exposure.

The use of swiftlet feathers as bioindicators in this study offers a novel and non-invasive approach to monitoring environmental pollution. Feathers accumulate heavy metals from contaminated air and food sources, and their composition correlates positively with internal tissue metal levels. This characteristic makes swiftlet feathers a practical and reliable tool for assessing heavy metal contamination across diverse environmental settings. Additionally, the long-range flight capability of swiftlets, spanning up to 200,000 km annually, allows them to reflect a wide spectrum of environmental exposures, further enhancing their utility as bioindicators.

This study contributes new insights into the environmental impact of heavy metals and underscores the importance of targeted pollution mitigation strategies in industrial and urban areas. It also reinforces the potential of swiftlet feathers as a bioindicator for assessing ecological health, offering a scalable and non-invasive approach to environmental monitoring. These findings serve as a foundation for further research into heavy metal contamination and its broader ecological implications. It is also recommended that in the future we can examine the heavy metal content in other parts of the swiftlet, or in its nest.

Conclusion

This study demonstrates higher Cr and As levels in swiftlet feathers from Gresik compared to Nganjuk, reflecting the impact of industrial activities. The elevated levels in Gresik are likely due to its proximity to industrial activities and dense urban areas, which contribute to greater environmental pollutant deposition. In contrast, the relatively natural surroundings of the swiftlet houses in Nganjuk result in lower heavy metal accumulation. While the results highlight the utility of swiftlet feathers as bioindicators, future research should address the limitations of sample size and data diversity. Additional measurements from other biological matrices and increased sampling will enhance the understanding of heavy metal bioaccumulation.

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